Central Light Rail Line

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L.1 INTRODUCTION

This document serves as the Fleet Management Plan for the Central Light Rail Line (CLRL), the Baltimore regional light rail service provided by the Maryland Department of Transportation, Mass Transit Administration (MTA). The purpose of the plan is to document existing operations and maintenance procedures and determine how efficiently the CLRL's supply of vehicles is being utilized to accommodate current and anticipated future levels of ridership demand for the system.

The Fleet Management Plan is especially valuable to both the MTA and the Federal Transit Administration (FTA) in understanding the proportion of light rail vehicles which must be kept as spares in order to preserve the system's service structure. Given that the FTA maintains no spare ratio requirements, the Fleet Management Plan serves to explain how an agency's spare ratio is tailored to meet the needs of its operating environment. Moreover, the MTA Fleet Management Plan has been selected by the FTA to be included in a report of best practices in fleet management used in the United States. This report will be distributed to rail transit agencies throughout the United States.

Specific guidance for creating the CLRL Fleet Management Plan was taken from FTA Circular 9030.1B, Chapter V, Section 15, entitled, "Fixed Guideway Rolling Stock." Additional guidance was taken from a February 8, 1997 memo from Hiram J. Walker, Associate Administrator for FTA Program Management.

L.2 DOCUMENT ORGANIZATION

The CLRL Fleet Management Plan is organized as follows:

- Overview of the CLRL.
- Analysis of passenger and fleet demands.
- Analysis of revenue vehicle supply.
- Comparison of revenue vehicle supply and demand.

L.3 OVERVIEW: CENTRAL LIGHT RAIL LINE

L.3.1 GENERAL SYSTEM INFORMATION

The Central Light Rail Line consists of 33 stations distributed along 29.5 miles of right-of-way (see Figure L-1). The line includes segments of both in-street running and dedicated right-of-way. Both single- and double-tracked sections exist along the line. Trains are required to yield to opposing rail traffic at single-tracked sections.

Trains operating in downtown Baltimore are connected to a signal preemption system. Outside of the downtown area, light rail at-grade crossings are gated, giving light rail priority.

The Central Light Rail Line is one of the few LRT lines which has freight operations on its tracks. Freight trains typically operate on light rail tracks during non-revenue hours. However, some freight consists moving between the Conrail Flexi-Flow Yard and the Northeast Corridor cross the light rail tracks during revenue hours.

L.3.2 CLRL LINES: HISTORY AND OPERATIONS

The system is composed of two services (see Figure L-1.) The original CLRL line (hereafter referred to as the "Main Line") began operations in April 1992. This line ran from the northern suburb of Timonium, through downtown Baltimore, and south to Cromwell Bridge Road in Glen Burnie. In late 1997, this line was extended north to the Hunt Valley Mall.

In December 1997, the MTA began operations between Baltimore-Washington International Airport (BWI) and Penn Station. This service operates on a pair of spurs off the Main Line. BWI/Penn Line trains begin at Penn Station, continue down a spur to the Mt. Royal Station, serving the Main Line stations between and including Mt. Royal and Linthicum. South of the Linthicum Station, BWI/Penn Station trains branch off to serve the stations at the BWI Business District and the BWI main terminal.

Together, the Main Line and Penn Station/BWI service interface with virtually every mode of transportation in the Baltimore metropolitan area. The majority of light rail stations are served by regular MTA bus routes. 13 of the stations have park-and-ride facilities, providing a total of 3,237 parking spaces. Connections to the Camden Line of the MARC commuter rail service may be made at Camden Yards, while the Penn Station light rail station offers access to MARC's Penn Line and the intercity rail services offered by AMTRAK. Finally, the light rail station at Baltimore-Washington International Airport offers direct access to the airport's main terminal.

Regularly-scheduled CLRL trains operate between 5:00 A.M. and 11:00 P.M. on weekdays. On Saturday, trains operate between 8:00 A.M. and 11:00 P.M. On Sunday, trains operate between 11:00 A.M. and 7:00 P.M. Service hours are extended as necessary to serve ball games and other special events. The CLRL operates 17-minute headways on the Main Line and 17-minute headways between BWI and Penn Station.

MTA light rail vehicles (LRVs) are stored and maintained at two locations. The first is the main shop, located just north of the North Avenue Station. This shop has an estimated capacity to support 43 vehicles. (Up to 44 LRVs can be stored in the yard at gridlock.) The second location is the Cromwell storage facility, recently opened at the southern terminal of the

system. This facility allows for daily inspections, daily cleaning, and minor corrective maintenance (e.g. replacing a light bulb in the coach.) Maintenance issues are discussed in greater detail in Section L-4, "Revenue Vehicle Demand."

L.3.3 EXISTING FLEET

The MTA has 53 light rail vehicles in operation. All cars operate on electric motors which receive power from overhead catenary lines. The vehicles are 100% compatible with one another and are equipped for operations as single cars. The fleet may be operated in consists with multiple cars; however, the length of CLRL station platforms and the length of downtown Baltimore city blocks limit light rail consists to a maximum of three cars. Each vehicle has a capacity of 84 seated passengers and 166 standees.

Currently, each CLRL vehicle operates an average of 60,000 miles annually, including revenue and deadhead mileage. Overall, the system maintains an on-time performance record of 99.5%. (On - time performance is measured from terminal-to-terminal, rather than from station-to-station.)

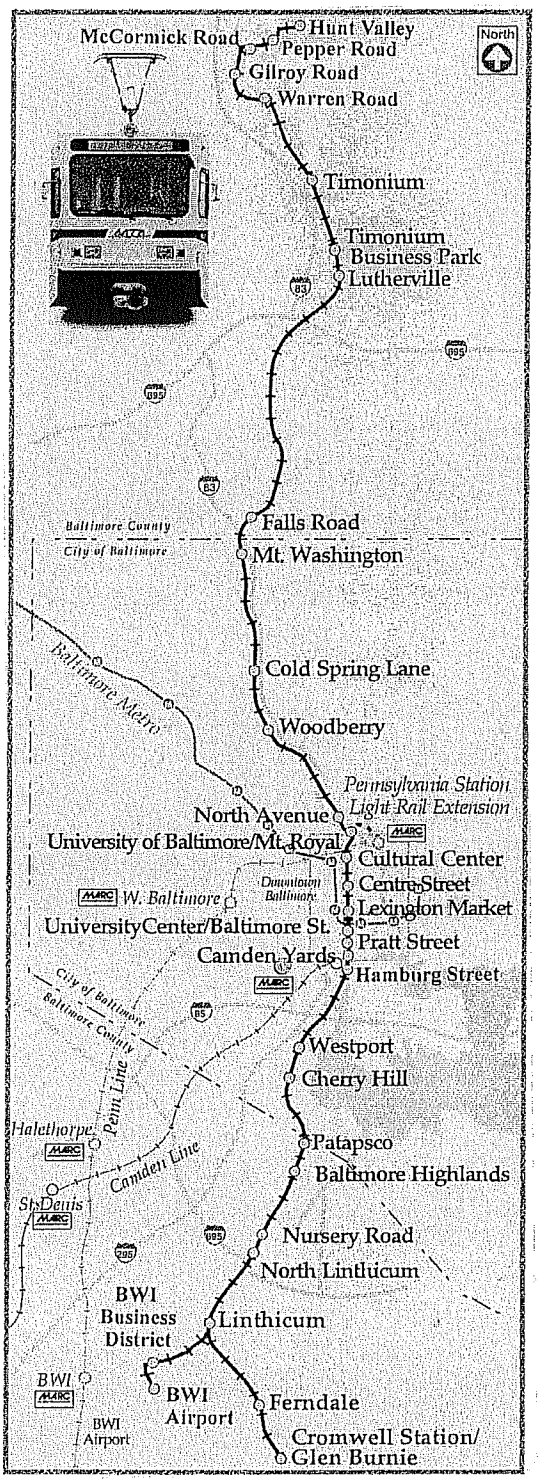

Figure L-1

L.4 REVENUE VEHICLE DEMAND

L.4.1 RIDERSHIP TRENDS

Since the Central Light Rail Line began operations in April 1992, ridership has exhibited an overall upward trend. Figure L-2 illustrates the average daily ridership trends between February 1996 and October 1999. As of October 1999, the CLRL had an average daily weekday ridership of approximately 27,000an increase of 30% since October 1999. This increase may be attributed in part to the recent Hunt Valley and BWI/Penn Station extensions. It should be noted that actual daily ridership varies significantly from the average, with special events such as ball games, celebrations at the Inner Harbor, and events at the Convention Center generating higher volumes of ridership.

L.4.2 VEHICLE REQUIREMENTS

L.4.2.1 Peak Vehicle Requirements

Figure L-3 summarizes the peak vehicle needs of the Central Light Rail Line. Note that, in the absence of formal loading standards, the MTA has established its Peak Vehicle Requirements according to basic service needs for each line.

A brief explanation of standby cars is necessary. The MTA maintains four, one-car consists on "hot" standby in the North Avenue yard, allowing these vehicles to be brought into service quickly should a train in operation malfunction or otherwise need replacement. There are four common scenarios under which standby cars are deployed:

1. In order to remove a revenue vehicle from service for graffiti removal or as a result of a sickness/injury requiring imme -diate cleaning and/or repair.
2. In order to remove a revenue vehicle from service which requires immediate attention to prevent an existing fault from escalating into a critical failure.
3. To assist in recovering from service delays.
4. In situations where a vehicle must be removed from service when it becomes part of a crime scene and is required in the investigation process.

Because standby cars are critical to maintaining on-time performance, they are considered part of the Peak Vehicle Requirement.

When revenue trains and standby trains are added together, a total of 32 LRVs are necessary for peak operations.

L.4.2.2 Off-peak Vehicle Requirements

During midday operations, consist lengths and headways remain the same as during peak operations. Therefore, midday operations require 32 LRVs, the same number of vehicles as peak hour operations. After 6:00 P.M. on weekdays and all day on Sunday, all CLRL services operate with single-car consists (except during special events, which will be explained later in this section.) This brings the evening and Sunday vehicle requirement down to a total of 18 LRVs.

Saturday service utilizes two-car consists on the Main Line and single-car consists on the BWI/Penn Line. Thus, the vehicle requirement for Saturday services is 32 LRVs.

L.4.2.3 Special Event Requirements

The Central Light Rail Line's connections to both stadiums, the convention center, and downtown Baltimore makes it well-suited to serving numerous special events in the area. There are approximately 200 special events a year served by light rail, the most frequent of which are the 81 regularly-scheduled baseball games of the Orioles.

FIGURE L-2: DAILY RIDERSHIP TRENDS, 1996-1999

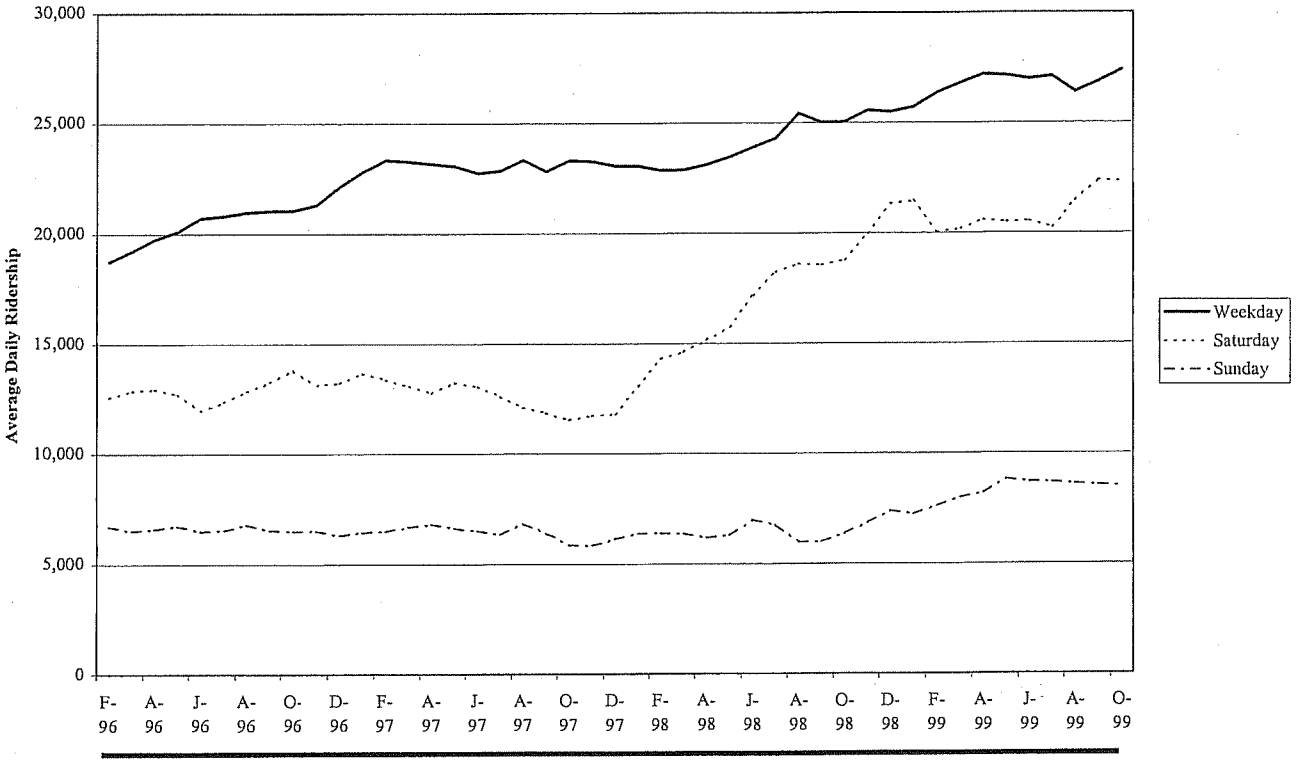

FIGURE L-3: PEAK VEHICLE REQUIREMENTS

	Regular Service	Special Events/ Orioles Games	Ravens Games
Basic headways:			
Main Line:	17 minutes	17 minutes	17 minutes
BWI/Penn Station:	17 minutes	17 minutes	17 minutes
Trains necessary to maintain headways:			
Main Line:	11 trains	11 trains	13 trains*
BWI/Penn Station:	6 trains	6 trains	6 trains
Standby:	4 trains	4 trains	0 trains
Vehicles per consist:			
Main Line:	2-car	3-car	3-car
BWI/Penn Station:	1-car	2-car	2-car
Standby:	1-car	1-car	NONE
Peak Vehicle Requirements:			
Main Line:	22 cars	33 cars	39 cars
BWI/Penn Station:	6 cars	12 cars	12 cars
Standby:	4 cars	4 cars	NONE
Total	**32 cars**	**49 cars**	**51 cars**
% of Total Fleet	**60%**	**93%**	**96%**

*NOTE: During Ravens games, two, 3-car trains are kept on hot standby then placed in service to handle the "away" movement.

Other special events include:

- Ravens football games
- New Year's Eve
- Maryland State Fair
- Baltimore Artscape
- Fourth of July
- Arena events
- Conventions
- Circus (10 days in March)
- Concerts at the Inner Harbor
- Additional events at PSINet Stadium

In all, MTA spends approximately one-third of the calendar year providing service to special events.

Service and vehicle requirements vary by special event:

Football games The Hamburg Street Station has been opened recently to accommodate the ridership demands of Ravens football games. Because football crowds tend to exit all at once rather than trickling out during the last half of the game, Ravens games generate the greatest load factors faced by light rail revenue vehicles.

The MTA uses three-car consists on the Main Line and two-car consists on the BWI/Penn Line for the hours before, during, and after football games. In addition, two, three-car consists are kept in "pocket tracks" to assist in the away movement when a football game lets out. Including the consists on the pocket tracks and regularly scheduled trains, 51 LRVs are required for special services during football games.

As a special service for football games, light rail operations are extended by three hours before football games. Service are also extended after football games for as long as necessary to clear the Hamburg Street platform. It takes an average of 1.5 hours to clear the platform.

Baseball games Baseball games also generate significant load factors; however, since crowds tend to filter out during the last innings of a game, the peak demands are relatively less than those of football games.

As with football games, light rail special service for baseball games uses three-car consists on the Main Line both three hours before baseball games and one hour after the game ends. Baseball games days require a maximum of 49 LRVs for operations.

Other special events The service hours maintained during special events vary and may be extended as necessary. For all special events, the MTA uses three-car consists on its Main Line. The use of pocket trains varies by event. With three-car consists on the Main Line and without using pocket trains, special events operations require 49 LRVs.

The frequency of special events in the CLRL service area places a significant demand on the fleet of revenue vehicles. This must be taken into consideration when evaluating CLRL fleet management practices.

L.4.3 PEAK VEHICLE DEMAND

Because the majority of transit boardings throughout the year occur during the morning and evening rush hours, it is necessary to determine if the existing service schedule provided by the CLRL is sufficient to accommodate peak ridership demands. As detailed on-off counts for 1999 ridership are not available, the following methodology was established to estimate peak vehicle demands:

1. The historical percentage of daily passengers riding during the peak 15 minutes of the evening peak period was calculated.

$$\%\ 1996\ \text{Ridership in Peak 15 min.} = \frac{\text{1996 Ridership at Critical Load Segment}}{\text{1996 Average Weekday Ridership}}$$

The last comprehensive ridership study was completed in Winter 1996. In this study, on-off counts were recorded, providing a detailed

account of load factors for each station-to-station segment of the line. The highest ridership for any train in this study-258 passengers-occurred between the Lexington Market and Centre Street Stations between 5:00 P.M. and 5:15 P.M.

The percentage of total ridership on this segment was calculated as follows:

% 1996 Ridership in Peak 15 min. = 258 passengers/20,069 daily weekday boardings

= 1.3% of total daily weekday boardings

2. Current ridership patterns were observed and compared with historical patterns to identify the critical load segment (i.e. the station-to-station link where the maximum ridership for a single, peak hour, peak direction train occurs.) Because the CLRL has recently been extended to serve Hunt Valley, BWI, and Penn Station, an observer was sent to ride peak hour trains to determine if peaking patterns had been affected by these service improvements. Although no detailed on-off counts were made, the observer indicated that peak loads are still occurring on Main Line trains between the Lexington Market and Centre Street Stations.

3. Ridership during the peak 15 minutes was estimated using historical load factors and observed ridership patterns.

1999 Ridership at Critical Load Segment =
% 1996 Ridership in Peak 15 min.
x 1999 Average Weekday Ridership

As the location of the critical load segments has not changed, it can be assumed that the peak load factor has remained relatively constant. Applying a peak load factor of 1.3% to the average daily ridership of October 1999:

1999 Ridership at Critical Load Segment
= 27,382 boardings/day x 1.3%
= 356 passengers

4. Estimated ridership during the peak 15 minutes was distributed among the vehicle capacity available during this time period. Each peak hour train operating on the Main Line is capable of accommodating a total of 500 passengers (168 seated, 332 standees.) One, peak-direction train passes the critical load segment during the peak 15 minutes. Therefore, at the critical load segment:

356 passengers/500 spaces = 71.2% capacity

$\frac{\text{356 passengers - 168 seats}}{\text{356 passengers}}$ = 52.8% passengers standing

Based on these calculations, the existing service schedule is sufficient to meet the regular demands of peak ridership. However, three, additional points should be taken into account:

1. These calculations do not take into account the impact of wheelchairs. Each LRV is capable of accommodating passengers in wheelchairs. However, the areas designated for wheelchair travelers require three seats to be folded up. This impacts the total capacity of a train.

2. These calculations do not take into account the additional demands of special events coinciding with peak hour, peak direction travel. In such cases, existing LRVs may be required to operate at crush capacity.

3. The calculations above are for Main Line capacity only. BWI/Penn Line trains provide

NOTE: Comprehensive ridership information is obtained by sending observers to each station platform to count the boardings and alightings of each train in each direction from 4:30 A.M. to 1:30 A.M. Due to the manpower needs of this methodology, such surveys are only done once every few years. The latest comprehensive ridership survey is currently being completed. Annual ridership surveys are completed for the National Transit Database; however, these surveys do not provide station-to-station ridership information.

additional seating capacity between the University of Baltimore/Mount Royal Station and the Linthicum Station. However, as the majority of ridership at the critical load segment comes from north of the University of Baltimore/Mount Royal Station, this capacity is of limited utility to peak-hour passengers.

L.4.4 FUTURE VEHICLE DEMAND: RIDERSHIP ESTIMATES

A key component of fleet management is determining whether the existing fleet is sufficient to handle future levels of ridership. Ridership projections for the Central Light Rail Line were projected out to 2006, the year when the current fleet will undergo its midlife overhaul. These projections were based on the following assumptions:

- Ridership will increase at a rate of 5% per annum.
- No new light rail extensions are planned.
- Main Line trains will continue to use two-car consists.

It should be noted that the projected increase in ridership takes into account the potential ridership increases made possible by the Light Rail Double Track Project. This project is discussed in greater detail in Section L.4.5. Ridership forecasts will be refined as the Double Track Project proceeds and new service plans are evaluated.

Ridership projections and their impacts on peak vehicle capacity are displayed in Table L-1. Based on these estimates, the existing fleet deployment should be sufficient to handle moderate increases in ridership through the year 2006. However, periodic crowding on light rail trains may occur when Orioles games and other special events coincide with evening peak hour ridership.

L.4.5 FUTURE VEHICLE DEMAND: EFFECTS OF INFRASTRUCTURE IMPROVEMENTS

There are two changes to the system infrastructure which could affect the service and maintenance demand on the light rail fleet: the proposed introduction of a shop facility to the Cromwell storage facility and the proposed Light Rail Double Track Program.

L.4.5.1 Cromwell Shop Facility

In June 1998, the MTA opened a storage facility at Cromwell, the southern terminal of the Main Line. This facility is designed to supplement the main yard by taking care of some light maintenance such as daily inspections and daily vehicle cleaning.

The MTA is currently studying the potential of expanding the Cromwell facility to handle weekly, 45-day, and annual inspections of all light rail vehicles. Shifting these tasks to the Cromwell facility will free up some space at the North Avenue yard and shop for more time-consuming maintenance procedures. This will be especially critical in 2002, when the older LRVs are scheduled for their 10-Year Overhaul at the same time that the most recent additions to the fleet are undergoing their 5-Year Overhaul. (A more detailed discussion of fleet maintenance needs is provided in the following section.) In addition, the Cromwell facility should decrease the time necessary to dispatch vehicles to handle special events.

At this time, the vehicle capacity of the planned maintenance facility is estimated at 24 light rail vehicles. The facility should be completed in late 2001.

L.4.5.2 Light Rail Double Track Project

The proposed double-tracking of the Main Line will make it possible to shorten headways on both the Main Line and the BWI/Penn Station services. Existing single-track sections result in capacity constraints, putting limitations on the minimum headways feasible on the existing system. The proposed double-tracking program will remove these constraints.

Table L-1. Estimated Light Rail Ridership, 1998-2006

Year	Average Daily Ridership	Peak 15 min. AM Ridership	% Train Capacity Used at Peak 15 min.
1999*	27,382	356	68.2%
2000	28,751	374	71.6%
2001	30,189	392	75.2%
2002	31,698	412	78.9%
2003	33,283	433	82.9%
2004	34,947	454	87.0%
2005	36,694	477	91.4%
2006	38,529	501	96.0%

*1999 ridership figures for October 1999.

In addition, the double-tracking program will lengthen the window of opportunities for maintenance. The double-track configuration will allow regular service vehicles to bypass malfunctioning vehicles, improving the ability of the CLRL to preserve on-time performance.

Environmental assessments for the double-tracking program are underway. The MTA is currently preparing conceptual operations plans and other studies to determine the costs and feasibility of double-tracking. The effects of service changes on Fleet Management will be evaluated as operations planning and engineering moves forward.

L.4.6 SUMMARY: VEHICLE DEMAND

Current trends indicate that ridership on the Central Light Rail Line is increasing. Based on observed and estimated peak hour ridership patterns, two-car consists should be sufficient to handle the demand for passenger capacity during regular, peak hours of operation. However, light rail trains are experiencing overcrowding when special events (e.g. Oriole home games) coincide with evening peak hour operations.

L.5 VEHICLE MAINTENANCE REQUIREMENTS

Proper fleet management requires a basic understanding of the effects of maintenance schedules on vehicle availability. The following is a summary of CLRL maintenance practices.

L.5.1 MAINTENANCE CYCLES

Table L-2 summarizes the maintenance schedule for light rail vehicles. These schedules have been based on manufacturer specifications and recommendations and expanded upon to incorporate "lessons learned" from vehicle operations and repair histories.

Table L-2
LIGHT RAIL INSPECTION CYCLES

Inspection	Time Vehicle Out of Service	Labor Hours
Weekly	2 hours	2 hours
45-Day	12 hours	14 hours
Annual	100 hours	60 hours
5-year overhaul	64 hours	820 hours
10-year overhaul	TBD	TBD
Midlife overhaul	TBD	TBD

Weekly: Under this inspection, all safety-sensitive systems (e.g. door operations, communications equipment, brakes) are checked for defects. This inspection takes approximately one hour to complete using one hour of labor. An addition-

al hour is necessary for yard operations to move the vehicle into place.

45 Day: This inspection provides a detailed review of electrical, mechanical, and pneumatic systems. Critical items are adjusted, lubricated, repaired, and cleaned. Filters are replaced, and critical fluids are measured and refilled as necessary. The sensitivity and timing of various systems are recorded and adjusted. The 45 Day inspection takes two mechanics approximately 14 hours to complete.

Annual: During the annual inspection, all of the vehicle's mechanical, electrical, and pneumatic systems are examined. The annual inspection is inclusive of the procedures completed in the 45 Day inspection. It also includes procedures such as: coupler height adjustments, oil analysis, and dynamic brake rate analysis. The inspection requires two mechanics working consecutive day shifts to complete. As a result, the LRV must be kept out of service for approximately 100 hours and requires a total of 60 labor hours.

Five-Year Overhaul: The 5-Year Overhaul is a three-year program affecting all vehicles in the fleet. This overhaul is done in modules, where modules are changed out from vehicles as vehicles become available. The subsystems of the module are then repaired and/or replaced as need be. Conducting the Five-Year Overhaul in this manner reduces vehicle downtime and helps keep trains in revenue service. The modules completed in the Five-Year Overhaul are as follows:

- Trucks
- Couplers
- Air Supply and Brake Systems
- Doors
- Floors
- HVAC
- Car Body

A total of 820 labor hours are necessary to complete all modules of the 5-Year Overhaul. This work is done over a period of 64 hours: 40 consecutive hours for the floor and car body overhauls, 24 additional for all other components.

Ten-Year Overhaul: The 10-Year Overhaul is inclusive of both the 5-Year Overhaul and the annual inspection. In addition, more comprehensive, time-consuming work is also completed. While the 10-Year Overhaul is anticipated to be a modular process, work on some systems will require cars to be taken out of service. The total amount of time necessary to complete a 10-Year Overhaul has yet to be determined.

Midlife Overhaul: The midlife overhaul is to be completed in the fifteenth year of a vehicle's service life. The details of this overhaul have yet to be determined; however, this overhaul should be inclusive of all previous cycles (i.e. annual inspection, 5-Year Overhaul, and 10-Year Overhaul.)

In addition to the maintenance cycles, all light rail vehicles are subject to a regular cleaning schedule (see Table L-3.) The cleaning procedures take less time than any individual inspection cycle, but they occur more frequently than maintenance inspections and affect all revenue vehicles. Cleaning work is subcontracted out by the MTA.

The need to move all vehicles through cleaning facilities increases the amount of time necessary to "shuffle" vehicles in the yard. This delay, in turn, increases the amount of time necessary to move vehicles into position for maintenance procedures.

L.5.2 MAINTENANCE FACILITIES AND LABOR

The procedures and inspections listed above are carried out at the North Avenue Yard and Shop,

Table L-3
LIGHT RAIL CLEANING CYCLES

Inspection	Time
Daily	1/2 hour
Bi-Weekly	2 hours
Quarterly	5 hours
Seat Shampoo	As needed

with some daily inspections and cleaning work completed at the Cromwell storage facility.

The North Avenue Shop, the primary maintenance facility for the light rail system, consists of four maintenance tracks, each capable of holding two LRVs at one time. In addition, the shop contains one track used for a car wash. Table L-4 summarizes the uses of each track. Three of the five tracks in the shop -3, 4, and 5- are double-ended. The use of the stub-ended tracks can cause delays in the maintenance schedule when one or more trains must be moved out of the shop so that others may be admitted for work or inspections. These delays, in turn, put an upper limit on the total number of vehicles which may be regularly maintained at the existing facility.

The new facility at Cromwell has a storage capacity of 18 LRVs and is operated by a staff of ten. The Cromwell storage facility is capable of performing minor maintenance, daily inspections, and daily cleaning, thereby freeing up some space at the North Avenue yard.

A 1995 study of MTA light rail maintenance practices estimated that the existing North Avenue yard and shop has an effective capacity of 40-44 LRVs. The recent addition of the Cromwell storage facility increases the capacity of CLRL yard and shop facilities.

The MTA light rail car maintenance staff currently consists of 41 union personnel operating seven days a week, four shifts per day. The majority of this staff is deployed during the day shift, when heavy maintenance and repair work is performed on LRVs. Table L-5 lists the staffing levels for each shift. Additional staffing needs will be evaluated as plans for the expanded Cromwell facility are refined.

L.5.3 ROUTINE SCHEDULED MAINTENANCE DEMAND

The impacts of routine, scheduled maintenance on the daily availability of light rail vehicles are displayed in Table L-6. The calculations used to derive these estimates are included in Appendix A. Because Daily and Weekly inspections are conducted after the evening peak, these inspections usually affect vehicle availability only when they uncover issues which require unscheduled maintenance.

The 45-Day inspection, Annual inspection, and Five-Year Overhaul are all performed during regular hours of revenue service and impact the availability of vehicles for revenue operations. Table L-6 estimates that the 45-Day inspection takes approximately one LRV out of service every day, while the Annual inspection takes one LRV out of service every other week. (Note that it takes approximately four, consecutive days to perform an Annual inspection on one LRV.)

Because the original fleet of 35 LRVs is now reaching (or passing) its fifth year of operations, the Five-Year Overhaul is having a greater affect on maintenance demands than previously experienced by the fleet. While the time and resources necessary for the overhaul vary by vehicle, an average of one LRV a week is removed from service to meet the needs of the overhaul. Table L-6 shows that for the existing and planned fleet, between 1.2 and 1.4 LRVs a day are necessary to meet the demands of the regular inspections and maintenance. This number increases to two LRVs when an annual inspection is being performed, and increases again when a Five-Year Overhaul is necessary. All told, on a regular day of operations, up to three LRVs may be out of service for scheduled maintenance.

As mentioned above, the daily maintenance demands of the 10-Year Overhaul and Midlife Overhaul have yet to be determined. However, it should be noted that the 10-Year Overhaul will

be performed on the original fleet at the same time that the newest vehicles are undergoing their 5-Year Overhaul. The expansion of the Cromwell facility should help to accommodate this overlap in maintenance cycles. Additional maintenance issues will be addressed as preparations for the 10-Year Overhaul progress.

L.5.4 UNSCHEDULED MAINTENANCE HISTORY

The majority of LRV maintenance demands are imposed by unscheduled and corrective maintenance. The following is a sample of the issues generating these unscheduled maintenance demands:

Engineering design changes. Where systems have been observed to exceed acceptable 'in service' failure rates, the MTA has made engineering design changes.

Fleetwide defects. Examples of this issues include (a) the ongoing roof repair project; and, (b) the Electrical Connector Replacement project.

Fleetwide modifications. For example: the installation of a second pantograph.

Collision damage. On average, there are two-to-three collision accidents between LRVs and automobiles every week. The majority of these accidents occur in the Baltimore Central Business District, where the CLRL runs at-grade along Howard Street. Such accidents have resulted in two "long term" repairs (i.e. repairs requiring a vehicle to remain out of service for up to six months.)

Miscellaneous maintenance needs. Such needs include wheel truings and post-game graffiti removal.

Adding to this unscheduled demand is the mileage put on the average vehicle. The original fleet was procured with the intention of operating each LRV an average of 40,000 miles annually. Under the existing service structure, each LRV is averaging 60,000 miles a year. This increased mileage translates into the increased "wear and tear" of certain components. To account for the additional "wear and tear" created by these additional miles, regular MTA light rail maintenance practices have been expanded to go beyond the manufacturer's maintenance requirements.

On average, between four-to-five LRVs a day may be out of service for corrective maintenance. Between scheduled and unscheduled maintenance, up to eight LRVs may be pulled out of every day for daily maintenance requirements.

L.6 REVENUE VEHICLE SUPPLY

L.6.1 EXISTING FLEET

As noted, the current light rail fleet consists of 53 ADtranz light rail vehicles. These vehicles are operated using AC traction motor propulsion systems, supplied with DC power from overhead catenary wires. The vehicles all have high-floors, requiring ramps on the station platform to accommodate wheelchair access. Additional vehicle specifications include:

- Length: 95 feet
- Width: 114 inches
- Capacity: 84 seated, 166 standees

Presently, LRVs are operated in one-, two-, and three-car consists. Consist length is constrained by the length of light rail station platforms and the length of downtown city blocks.

L.6.2 ADJUSTMENTS TO SUPPLY AND VEHICLE DEMAND

The supply of vehicles available for revenue operations is affected by three factors: vehicle procurements, vehicle retirements, and vehicle operations and maintenance.

L.6.2.1 Procurement

The MTA has no plans to procure additional light rail vehicles prior to the completion of the Light Rail Double Track Project.

L.6.2.2 Retirement

Table L-4
MAINTENANCE YARD TRACK FUNCTIONS

Track	Function
1	Light Repair; Weekly inspections; HVAC and pantograph
2	Light and Heavy Repair
3	Light Repair; Wheel Truing/Preventive Maintenance; Weekly Inspections
4	Light Repair; Weekly Inspections
5	Car Wash

Table L-5
MAINTENANCE STAFFING

Time	Personnel
7:00 AM-3:30 PM	20
3:00 PM-11:30 PM	8
11:00 PM-7:30 AM	10
9:00 PM-5:30 AM (Cromwell only)	3

Table L-6
AVERAGE DAILY DEMAND: REGULAR MAINTENANCE

Inspection	Frequency/ year/ vehicle	35 LRVs	40 LRVs	45 LRVs	50 LRVs	55 LRVs
45-Day	8.1	0.8	0.9	1.0	1.1	1.2
Annual	1.0	0.1	0.1	0.1	0.1	0.2
Five-Year Overhaul	1.0	0.1	0.1	0.1	0.1	0.2
Ten-Year Overhaul	TBD	TBD	TBD	TBD	TBD	TBD
Midlife Overhaul	TBD	TBD	TBD	TBD	TBD	TBD
Total Daily Demand		**1.0**	**1.1**	**1.2**	**1.4**	**1.5**

Table L-7
OPERATING SPARES RATIOS

Scenario	Total Active Fleet	Deployment	Peak Vehicle Requirement	Average Daily Maintenance Demand	Operating Spares Ratio
Regular Service	53	Main Line: 11, 2-car trains BWI/Penn Station: 6, 1-car trains 4 LRVs hot standby	32	5-8	66%
Ravens Home Game Service	53	Main Line: 13, 3-car tranist BWI/Penn Station: 6, 2-car trains	51	5-8	4%

All CLRL vehicles have been purchased in this decade and each have an anticipated service life of 30 years. Because of this, no vehicle retirements are planned for in the near future.

L.6.2.3 Vehicle Demand

With a fixed number of revenue vehicles and no scheduled vehicle retirements in the immediate future, the greatest factor affecting the supply of revenue vehicles will be operations and maintenance requirements.

On the operations side, the effects of the Hunt Valley and BWI/Penn Station extensions have increased the demand placed on the entire LRV fleet. This demand, in turn, increases the "wear-and-tear" placed on each vehicle and may eventually necessitate more frequent unscheduled maintenance. As a result, the number of LRVs unavailable for service may increase. This problem has been offset by the recent expansion of the fleet.

On the maintenance side, the introduction of the Cromwell storage facility will allow for a more efficient flow of vehicles through the North Avenue facility, thereby improving the ability to preserve the existing maintenance schedule for the fleet.

L.7 SUPPLY/DEMAND COMPARISON: OPERATING SPARES RATIO (OSR)

The historical and forecast maintenance demands of the fleet indicate that the peak vehicle operations require five-to-eight LRVs for daily scheduled and unscheduled maintenance needs. In short, the fleet requires a total of 37-40 LRVs (32 in service, five-to-eight for maintenance) for regular operations and maintenance. During Ravens games, the fleet requirement of operations and maintenance increases to between 56-59 LRVs (51 in service, five-to-eight for maintenance.) The existing fleet consists of 53 LRVs.

The supply of LRVs can be compared to the demand for vehicles using the Operating Spares Ratio. The standard calculation of an Operating Spares Ratio defined by the FTA is as follows:

$$OSR = \frac{TAF - PVR}{PVR}$$

Where: OSR represents the Operating Spares Ratio
TAF represents the Total Active Fleet
PVR represents the Peak Vehicle Requirement,including standby (or "gap") Vehicles and excluding vehicles necessary for regular maintenance.

Note that the OSR was computed for two, separate scenarios: regular, peak-hour service and Ravens home games. The results of these calculations are presented in Table L-7.

Based on the standard definition of the Operating Spares Ratio, the CLRL was calculated to have a 66% spares ratio during regular, peak-hour service. This ratio does not take into account the daily demands of maintenance and inspection schedules, nor does it take into account the effects of unscheduled and corrective maintenance on the availability of vehicles.

Table L-7 also illustrates that the existing fleet operates with a spares ratio of 4% during special events. Current ridership trends indicate that trains serving the peak 15 minutes of the peak hour and trains serving special events may experience passenger crowding.

L.8 CONCLUSIONS

The existing Fleet Management Plan allows the MTA to use a limited fleet of LRVs to provide excellent on-time performance and a consistent degree of passenger amenities. The frequency of special events in the CLRL service area place a significant demand on light rail services and creates instances where the Operating Spares Ratio is unacceptably low. While the recent expansion of the fleet to 53 LRVs has improved the spares ratio during special events, light rail trains still experience occasional overcrowding during peak hour travel and special events.
The availability of vehicles is also impacted significantly by current trends in scheduled, corrective, and unscheduled maintenance.

In summary, the existing light rail fleet performs at an Operating Spares Ratio of 66%. This percentage reflects the relatively small size of the fleet. It also does not properly reflect the demands of special event service schedules or regular preventive maintenance. Although the MTA light rail fleet is capable of meeting the additional demands of special event services, inefficiencies would result if the fleet were required to meet such demands on a regular basis. With these factors into consideration, the CLRL Fleet Management Plan provides for an efficient allocation of light rail vehicles.

Appendix A:
Calculation of the Average
Daily Demand of Scheduled Maintenance

The following methodology was used to estimate the average daily demands of scheduled maintenance:

1. Calculate the number of times each maintenance and inspection cycle must be performed on a single vehicle in the course of a year.

$$\#\ cycles/year = \frac{365\ days/year}{\#\ days/cycle/vehicle}$$

Example: 45-Day Inspection:

$$\#\ cycles/year = \frac{365\ days/year}{45\ days/cycle/vehicle}$$

$$\#\ cycles/year = 8.1\ cycles/year/vehicle$$

Therefore, one LRV will require approximately eight, 45-Day inspections in the course of a year.

2. For each maintenance cycle, multiply the number of cycles per year by the number of vehicles to determine the total number of maintenance cycles which must be performed on the entire fleet in the course of a year.

Total # of maintenance cycles for the fleet = # cycles/year x # vehicles

Example: 45-Day Inspection:

Total # of maintenance cycles for the fleet = 8.1 cycles/year x 35 LRVs

Total # of maintenance cycles for the fleet = 283.5 cycles/year

3. Divide the number of maintenance cycles for the fleet by the number of days in the year to determine the average daily maintenance demand of an inspection cycle.

Example: 45-Day Inspection:

$$Average\ Daily\ Maintenance\ Demand = \frac{283.5\ cycles/year}{365\ days/year}$$

$$Average\ Daily\ Maintenance\ Demand = 0.8\ Inspections/day$$

Appendix B:
Light Rail Car Maintenance
LRV Historical Review

Light Rail Car Maintenance
LRV Historical Review

Vehicle ID	Date Delivered	Date Accepted	Mileage To Date	Status
5001	10/01/91	08/22/92	390,446	In Revenue Service
5002	10/10/91	03/31/92	227,295	In Revenue Service
5003	11/23/91	03/31/92	433,000	In Revenue Service
5004	12/17/92	03/26/92	486,000	In Revenue Service
5005	12/27/91	02/11/92	224,000	In Revenue Service
5006	01/04/92	01/28/92	467,813	In Revenue Service
5007	01/29/92	02/11/92	463,680	In Revenue Service
5008	02/05/92	02/24/92	394,658	In Revenue Service
5009	02/11/92	02/26/92	266,000	In Revenue Service
5010	02/20/92	03/02/92	458,000	In Revenue Service
5011	03/27/92	03/18/92	453,161	In Revenue Service
5012	03/06/92	03/20/92	466,523	In Revenue Service
5013	03/19/92	03/20/92	461,000	In Revenue Service
5014	03/25/92	03/30/92	455,957	In Revenue Service
5015	03/31/92	03/30/92	432,000	In Revenue Service
5016	04/23/92	05/01/92	417,818	In Revenue Service
5017	04/30/92	05/14/92	453,000	In Revenue Service
5018	05/08/92	05/14/92	288,353	In Revenue Service
5019	05/21/92	06/03/92	439,336	In Revenue Service
5020	06/02/92	06/16/92	261,000	In Revenue Service
5021	06/18/92	07/20/92	268,000	In Revenue Service
5022	07/10/92	07/20/92	438,000	In Revenue Service
5023	07/28/92	08/13/92	218,000	In Revenue Service
5024	08/16/92	08/27/92	285,000	In Revenue Service
5025	10/05/92	10/25/92	249,100	In Revenue Service
5026	09/14/92	09/30/92	264,000	In Revenue Service
5027	10/07/92	11/19/92	484,000	In Revenue Service
5028	11/05/92	12/01/92	258,000	In Revenue Service
5029	12/04/92	01/07/93	478,930	In Revenue Service
5030	12/30/92	02/01/93	374,751	In Revenue Service
5031	01/27/93	02/22/93	374,751	In Revenue Service
5032	02/08/93	03/28/93	407,000	In Revenue Service
5033	03/24/93	04/08/93	524,439	In Revenue Service
5034	04/23/93	05/27/93	321,000	In Revenue Service
5035	05/13/93	05/27/93	406,949	In Revenue Service
5036	04/01/98	04/24/98	35,000	In Revenue Service
5037	09/17/97	03/30/98	34000	In Revenue Service
5038	03/26/98	04/16/98	41,000	In Revenue Service
5039	10/26/98	12/04/98	40,000	In Revenue Service
5040	03/12/98	03/27/98	66,000	In Revenue Service
5041	04/13/98	04/30/98	60,000	In Revenue Service
5042	05/18/98	06/04/98	55,000	In Revenue Service
5043	06/05/98	06/24/98	57,000	In Revenue Service
5044	06/24/98	07/24/98	51,000	In Revenue Service
5045	07/12/98	08/04/98	42,000	In Revenue Service
5046	07/30/98	08/07/98	50,000	In Revenue Service
5047	08/13/98	08/21/98	35,000	In Revenue Service
5048	09/14/98	09/25/98	46,000	In Revenue Service
5049	09/10/98	09/25/98	45,000	In Revenue Service
5050	09/18/98	10/16/98	46,000	In Revenue Service
5051	10/14/98	11/16/98	40,000	In Revenue Service
5052	11/06/98	12/09/98	39,000	In Revenue Service
5053	12/08/98	01/14/99	34,000	In Revenue Service

Total Maintenance Miles=
14,106,960
(Carbody Maintenance Miles)